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Project Summary

Stormwater Pollution Abatement Technologies

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The report summarized here presents information regarding best management practices (BMPs) and pollution abatement technologies that can provide treatment of urban stormwater runoff. The text includes a general approach that considers small storm hydrology and watershed practices that cover public education, regulations, and source control of pollutants. Also covered are source treatments of pollutants, which include vegetative BMPs and infiltration practices. Uses and modifications of installed drainage systems, types of end-of-pipe treatments including biological, chemical, and physical types and storage and reuse of stormwater are also covered.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The full report covers the control and treatment of stormwater in relation to the removal or reduction of the stormwater pollutant loads. Many of the pollution abatement technologies discussed will help attenuate stormwater flows. As they are generally designed for small storm events, however, they will not provide sufficient capacity for the large events. Although prevention of stormwater flooding is not discussed, a drainage system design should consider both pollutant and flooding aspects of stormwater.

Strategically, the best way to control and treat urban stormwater runoff is through a combination of regulations, BMPs, and treatment processes. The optimal combination will be site specific and depend on site characteristics, specific pollutants involved, and cost considerations.

Regulations and BMPs are effective tools in controlling urban stormwater runoff because they tend to be preventive in nature. Mandating effluent limits and creating zoning laws are regulatory examples. BMPs may include upgrading current systems, developing proper management techniques, using the existing drainage systems for in-line or in-sewer storage, or creating off-line storage facilities.

Designing devices that intercept or infiltrate stormwater runoff back into the groundwater system before it is introduced into the stormwater or combined sewer conveyance system can greatly save costs in the design and construction of treatment facilities. Examples of such devices are swales, filter strips, porous pavement, and stormwater wetlands.

General Approach and Strategy

Small Storm Hydrology

The selection of suitable abatement technologies requires an understanding of the size and distribution of storm events. Generally, the smaller storm events are the critical storms to consider, because for many parts of the country, 85% of all the rains are less than 0.6 in. (15 mm) in depth and can generate about 70% of the total annual storm runoff. The characteristics of small and large storms can be very different in terms of the runoff generated, pollutant load, and receiving water impacts. Frequent small storms have a more persistent effect, whereas less frequent large storms have a larger impact but allow time for recovery between events. For small storms, inaccurately estimating the initial abstractions and the soil infiltration rates can significantly change the calculated storm runoff pollutant load. Initial abstractions include the rainfall depth required to satisfy surface wetting, surface depression storage, interception by hanging vegetation, and evaporation. Together with soil infiltration rates, the initial abstractions need to be accurately estimated to calculate the storm runoff volume.

Strategy

Traditional wastewater treatment methods (i.e., secondary treatment processes) tend to operate under conditions closer to steady state and are usually unsuitable for the fluctuating loads of stormwater runoff. On the other hand, technologies used to control and treat combined sewer overflows (CSOs) are more suitable for stormwater runoff. Successful stormwater management to control urban storm runoff pollution requires an areawide approach combining prevention, reduction, and treatment practices/technologies. It is unlikely one method will provide the best solution to control the widespread diffuse nature of stormwater runoff and achieve the water quality required.

Establishing an urban storm runoff pollution prevention and control plan requires a structured strategy that should include: defining existing conditions; setting site-specific goals; collecting and analyzing data; refining site-specific goals; assessing and ranking problems; screening and selecting BMPs and treatment technologies; and, implementing, monitoring, and reevaluating the plan.

This strategy will provide the control goal(s) to be achieved — the goal(s) that are then used as the basis for selection of suitable technologies or approaches. The goal(s) should initially be broad and not specific as the process of reviewing the technologies or approaches available will in itself generate information to focus and refine the goal(s) to meet cost, level of control, public opinion, feasibility, and other restraints.

A flexible approach, which, through an iterative process of review and adjustment is focused to a specific action plan, is the only real method by which the complexity of urban stormwater can be managed. The specific action plan must also be subjected to reassessment once feedback on implementation is available.

The report is concerned with an overview of the abatement technologies available and reviews the technologies by separating the drainage system into three physical areas:

- watershed area (i.e., storm runoff generation/collection area),
- installed and/or modified/natural drainage system (i.e., conveyance pipes, channels, storage, etc.), and
- end-of-pipe (i.e., point source).

Technologies applicable to each of these areas can be divided into structural and nonstructural. The nonstructural technologies cover approaches such as public education, regulations, and local ordinances and mainly apply to the upstream collection area. The structural approaches are the main options for the drainage system and end-of-pipe areas and tend to be the more expensive items.

The optimal solution is likely to be an integrated approach that employs several practices and technologies. The management of the watershed using BMPs to prevent or control pollution at the source is apt to offer the most cost effective solution and tends to be the basis of many stormwater management plans. BMPs, the preferred option, are, however, not always feasible or sufficient to achieve the control objectives by themselves. For older and more heavily urbanized areas, BMPs are likely to have limited application, and some form of treatment before discharge may be required.

Implementation of any stormwater management program needs to meet financial and, probably, schedule restraints. Therefore, an early review and improved use of existing facilities offers several advantages. These options, probably the quickest and least costly to be implemented, must also meet the objectives developed from the earlier stormwater management planning process. Examples might include the enforcement of existing regulations to control soil erosion during construction activities and adaptation of existing stormwater storage intended for flood control so that it also provides quality control for small storm events. New installations should consider design for both flood control and pollutant removals.

Watershed Area Technologies and Practices

As already stated, BMPs are not suitable in every situation. It is important to understand which BMPs are suitable for the site conditions and can also achieve the required goals. The realistic evaluation for each practice includes: the technical feasibility, implementation costs, and long-term maintenance requirements and costs. It is also important to appreciate that the reliability and performance of many BMPs have not been well established, with most BMPs still in the development stage. This is not to say that BMPs cannot be effective but rather that they do not have a large enough bank of historical data on which to base design to be confident that the performance criteria will be met under the local conditions. The most promising and best understood BMPs are detention and extended detention basins and ponds. Less reliable in terms of predicting performance, but showing promise, are sand filter beds, wetlands, and infiltration basins.

The reported poor performance of some of the BMPs is likely to be a function of: the design, installation, maintenance, and/or suitability of the area. Greater attention to these details is apt to significantly reduce the failure rate of BMPs. Other important design considerations include: safety for maintenance access and operations, hazards to the general public through safety or nuisance, acceptance by the public, and assuming conservative performances in the design until the historical data can justify a higher reliable performance.

The previously mentioned goals for a stormwater management plan can be achieved in the watershed area via three basic avenues:

Regulations, Local Ordinances, and Public Education. This should be the primary objective because it probably is the most cost effective. Mainly nonstructural practices will be involved, and application to new developments should be particularly effective.

Source Control of Pollutants. Both nonstructural and structural practices can be used to prevent pollutants coming into contact with the stormwater and hence storm runoff. Management and structural practices include: flow diversion (keeping uncontaminated stormwater from contacting contaminated surfaces or water by a variety of structural means); exposure minimization (minimizing stormwater contact with pollutants by structure and management); mitigation (plans to recover released or spilled pollutants in the advent of a release); prevention (monitoring techniques intended to prevent releases); control of sediment and erosion; and infiltration.

Source Treatment, Flow Attenuation, and Storm Runoff Infiltration. These are mainly structural practices to provide upstream pollutant removal at the source, controlled stormwater release to the downstream conveyance system, and ground infiltration or reuse of the stormwater. Upstream pollutant removal provides treatment of stormwater runoff at the specific, highly polluting locations where it enters the stormwater conveyance system. Areas of this type include but are not limited to vehicular parking areas, vehicular service stations, bus depots, industrial loading areas, etc.

Source Treatment, Flow Attenuation, and Storm Runoff Infiltration

Vegetative BMPs

These practices have been the subject of many publications in the last 20 yr. Existing urbanized areas are unlikely to have the land space available for installation of many of these practices and, in these situations, their application will be restricted.

Swales are generally grassed stormwater conveyance channels that remove pollutants by filtration through the grass and infiltration through the soil. A slow velocity of flow, <1.5 ft/s (<46 cm/s), a nearly flat longitudinal slope, <5%, and a vertical stand of dense vegetation higher than the water surface, ≥6 in. (15 cm) total height, are important for effective operation.

Filter strips are vegetated strips of land that act as “buffers” by accepting storm runoff as overland sheet flow from upstream developments before discharge to the storm drainage system. Filter strips provide potential treatment mechanisms similar to that of swales.

Stormwater wetlands can be natural, modified natural, or constructed wetlands that remove pollutants by sedimentation, plant uptake, microbial decomposition, sorption, filtration, and exchange capacity. Note that natural wetlands are covered by regulations that limit discharges to the wetland and limit modifications to enhance the wetland performance.

Detention Facilities

One of the most common structural controls for urban storm runoff and pollution loading is the construction of local ponds (including wetlands) to collect storm runoff, hold it long enough to improve its quality, and release it to receiving waters in a controlled manner. The basic removal mechanism is through settling of the suspended solids (SS) with any associated pollutants, but controlled release will also attenuate the stormwater flows, which can benefit receiving streams that suffer from erosion and disturbance of aquatic habitat during peak flow conditions.

Extended detention dry ponds temporarily detain a portion of stormwater runoff for up to 48 h (24 h is more common) using an outlet control. They provide: moderate but variable removal of particulate pollutants; negligible soluble pollutant removal; and quick accumulation of debris and sediment. Performance can be enhanced by using a forebay to allow sedimentation and easier removal from one area.

Wet ponds have greater capacity than the permanent volume of the pond; this permits storage of the stormwater runoff and controlled release of the mixed influent and permanent pond water. They can provide moderate to high removal of particulate pollutants and reliable removal rates with pool sizes ranging from 0.5 to 1.0 in. (12.7 to 25.4 mm) of storm runoff per impervious acre. Wet ponds offer better removals and less maintenance than do dry ponds. But they need to be well designed to ensure beneficial use and not cause aesthetic, safety, or mosquito breeding problems. A forebay here also improves performance and maintenance.

Infiltration Practices

These practices have a high potential to control stormwater runoff by disposing of it at a local site. Infiltration in its simplest form involves maximizing the pervious area of available ground to allow infiltration of stormwater and minimize the storm runoff. This can be enhanced by directing storm runoff from impervious paved and roof areas to pervious areas, assuming sufficient infiltration capacity exists. Regulations that encourage the incorporation of a high proportion of pervious areas, particularly for new developments, can be effective; however, soil and water table conditions have to be suitable, a conservative design has to be used, and maintenance has to be undertaken to minimize the possibility of system failure. The possible effects the storm runoff could have on the groundwater must also be considered. These could range from a relatively minor local raising of the water table that results in reduced infiltration rates to more serious pollution of the groundwater, particularly if this is also used as a water source. In many cases stormwater runoff will have low levels of pollution; however, the long-term effects of pollutant buildup in the soil and/or groundwater from storm runoff infiltration is not well known. Therefore, infiltration of urban storm runoff, especially from industrial and commercial areas that have higher levels of pollution, should be treated with caution.

Infiltration of storm runoff can offer significant advantages of controlling storm runoff at the source, reducing the risk of downstream flooding, recharging groundwater, and supplying groundwater to streams (i.e., low-flow augmentation or maintaining stream flow during dry-weather periods). These advantages need to be judged against any pollution risks from urban runoff.

Infiltration trenches, infiltration basins, and porous pavement are all applications of infiltration practices. Performance of these applications can be improved through regular maintenance, protective practices against clogging (e.g., protective screening from nearby construction), grass filter strips to filter out particulates, and sub-surface piping installed to direct the stormwater away.

Installed Drainage System

Control practices that can be applied to the drainage system are relatively limited, especially for existing systems, and involve the removal of illicit or inappropriate cross-connections, catchbasin and inlet cleaning, critical source area treatment devices, infiltration, and in-line and off-line storage.

New separate (or combined) systems can take advantage of increasing the pipe size and gradient to provide in-line storage and self cleaning, respectively. Existing separate (or combined) drainage systems can be modified for in-line storage by adding flow control devices (weirs, flow regulators, etc.).

Established urban areas with separate stormwater drainage systems are most likely to have an existing stormwater pollution problem that needs to be rectified.

Critical Source Area Treatment Devices

Research into the source of stormwater pollutants has shown that certain critical source areas can contribute a significant portion of the total urban storm runoff pollutant load. Treatment of the critical source areas can, therefore, offer the potential for a greater benefit than end-of-pipe or drainage system control, to reduce downstream pollutant loads. Potential critical sources include: vehicle service, garage, or parking areas; storage and transfer yards; and industrial materials handling areas exposed to precipitation.

In-line Storage

In-line storage uses the unused volume in the drainage system network of pipes and channels to store storm runoff that can also be provided by storage tanks, basins, tunnels, or surface ponds connected to the conveyance network. In-line storage will probably not offer any treatment in itself as the intent will be to make the system self-cleaning to reduce maintenance requirements. If storage is combined with an end-of-pipe treatment, however, the flow attenuation will help equalize the load to the treatment process and, hence, optimize the treatment plant size and costs. Other cost effective solutions might be found if existing treatment facilities can be used, such as connection to an existing wastewater system.

The degree to which the existing conveyance system can be used for storage is a function of: pipe or channel sizes; pipe or channel gradient (relatively flat lines provide the most storage capacity without susceptibility to flooding low areas); suitable locations for installation of control devices; and the reliability of the installed control. It is essential that accurate details of the existing system be collected from field surveys and as-built drawings. This allows the assessment of the storage capacity, number and locations of controls, and risk of upstream flooding. In new drainage system design, conveyance pipes and channels can be up-sized and hydraulic controls can be designed into the system for added system storage and routing.

Controls to restrict flow can either be fixed or adjustable. Fixed systems will probably be cheaper and require less maintenance. Some examples of fixed regulators are: orifices, weirs (lateral and longitudinal), steinscrews, hydrobrakes, wirbeldrossels, swirls, and stilling-pond weirs.

Adjustable systems can offer the advantage of being connected to a real-time control (RTC) system, which can be adjusted to hold back or release stormwater, to maximize storage capacity of the whole drainage system. The sophistication of an RTC system is unlikely to offer a cost effective solution for a separate storm drainage system unless there is a large in-line storage capacity and the stored runoff is to be treated. Typical examples of adjustable regulators are: inflatable dams, tilting plate regulators, reverse-tainter gates, float-controlled gates, and motor-operated or hydraulic gates.

Some of the above are relatively inexpensive, quick to install, and effective means of increasing storage. Also some will concentrate the heavier solids in the stored storm runoff for a more concentrated later release.

Off-line Storage

This refers to storage that is achieved by diverting flow from the drainage conveyance system when a certain flowrate is exceeded. The diverted water is stored until sufficient capacity is available downstream. Storage can be provided by any arrangement of basins, tanks, tunnels, etc. If gravity filling and emptying are not possible, pumping the water into or out of storage is involved.

Off-line storage can be designed to be relatively self-cleaning or to have facilities to resuspend the settleable solids. It can also be used to provide treatment by sedimentation with the sludge either collected or diverted to a wastewater treatment plant (WWTP).

Flow balance method (FBM) provides a means of storing discharged urban storm runoff in the receiving water. This is done by forming a tank with the use of flexible plastic curtains suspended from pontoons. The curtains are anchored to the receiving water bottom by concrete weights and the base of the tank is formed by the receiving water bed. The relatively low cost of the materials and construction gives this system cost advantages over conventional concrete and steel tank systems.

The FBM requires a suitable location and has limits on performance: a certain amount of mixing exists with the receiving water, not all the stored volume will be pumped back, and settleable solids require regular pumpback of the accumulated sediment. The quick construction potential of the FBM could favor the use of this system as a temporary measure in cases of a severe problem that needs attention. Since the FBM uses the existing receiving water, permits will probably be required.

Maintenance

Regular maintenance should be conducted for the drainage system and the controls to work efficiently. This generally consists of removing sediments from control devices, flushing drainage lines, and conducting inspections to identify any problems. Maintenance minimizes buildup of materials that can be flushed out by a surge from a large storm event and, thereby, minimizes the shock loading caused by intermittent storm events.

End-of-Pipe Treatment

Use of Existing Treatment Facilities

Use of existing facilities is apt to provide cost effective treatment as long as an economic means of connecting the stormwater drainage system to the facility is possible.

Spare capacity at the WWTP is one option, particularly if storage can be provided to equalize the storm runoff load. Even if the biological system has very little capacity, the primary treatment systems can often function well at somewhat higher overflow rates that, if combined with disinfection of the discharged storm runoff, will offer significant treatment. Stormwater also tends to have a higher percentage of heavier solids than does sanitary sewage, which will benefit removals at higher overflow rates.

An alternative could be to construct additional primary treatment at a WWTP to run in series with existing facilities during dry-weather flow (DWF) for improved treatment of DWF and to run in parallel during wet-weather flow for some control over the total flow. Also, use of any storage facilities, either at an end-of-pipe or at an upstream location, can provide treatment by sedimentation or storage to be released when treatment capacity is available.

Physical/Chemical Treatment

Physical/chemical treatment processes generally offer: good resistance to shock loads, ability to consistently produce a low SS effluent, and adaptability to automatic operation. Those described below are only suitable for removal of SS and associated pollutants. Other treatment methods (described more fully in the report), which may apply to a wider variety of stormwater pollutants, are high gradient magnetic separation and powdered activated carbon-alum coagulation. The extent of removals will depend on the SS characteristics and the level of treatment applied.

Screening can be divided into four categories with the size of the SS removed directly related to the screen aperture size (Table 1).

Table 1. Screening Categories

Screen Type	*Opening Size*
Bar screen	*>1 in. (>25.4 mm)*
Coarse screen	*3/16-1 in. (4.8-25.4 mm)*
Fine screen	*1/250-3/16 in. (0.1-4.8 mm)*
Microscreen	*<1/250 in. (<0.1 mm)*

Bar and coarse screens have been used extensively in WWTP at the headworks to remove large objects. Depending on the level of treatment required for the storm runoff, the smaller aperture sized coarse screens may be sufficient; however, a higher level of treatment can be achieved using the bar and coarse screens in conjunction with the fine or microscreens. Design of screens can be similar to that for WWTP and CSO. Consideration, however, must be given to stormwater characteristics of intermittent operation and to possible very high initial loads, which may not reflect WWTP operation characteristics. A self-cleaning system should be included for static screens to save manual cleaning during storm events together with automatic start up and shut down. Catenary screens (a coarse screen) are rugged and reliable and commonly used for CSO facilities. Therefore, they are likely to be a good screen for use with storm runoff.

Fine screens and microscreens have been developed and used for SS removal from CSO. The removal efficiency of screening devices is dependent on the aperture (size of opening) of the screen placed on the unit, making these devices very versatile. The efficiencies of a screen treating a waste with a typical distribution of particle sizes will increase as the screen aperture decreases.

Solids removal efficiencies are affected by two mechanisms: straining by the screen and filtering of smaller particles by the mat deposited by the initial straining. Suspended matter removal increases with the increasing thickness of filter mat because of the filtering action of the mat itself. This also increases the headloss across the screen. One study showed (on a 23 µm aperture microscreen [Microstrainer*]) that with a large variation in the influent SS, the effluent SS stayed relatively constant (e.g., both 1000 mg/L and 20 mg/L influent SS would give a 10 mg/L effluent SS). Accordingly, treatment efficiencies vary with influent concentration.

Generally, microscreens and fine screens remove 25% to 90% of the SS, and 10% to 70% of the BOD_5, depending on the screen aperture used and the wastewater being treated.

Dual-media high-rate filtration (DMHRF) (>8 gal/ft^2/min [20 m^3/m^2/h]) removes small particulates that remain after screening and floc remaining after polyelectrolytes and/or coagulants are added. As implied, this provides a high level of treatment that can be applied after screening together with automated operation and limited space requirements. Typically a unit is composed of 5 ft of No. 3 anthracite coal (effective size 0.16 in. [4.0 mm]) placed over 3 ft of No. 612 sand (effective size 0.08 in. [2.0 mm]). This arrangement was shown superior to both coarser and finer media tested separately.

Information is available on the use and design of DMHRF for treatment of drinking water, but a number of pilot studies have also been done with the use of CSO, which should provide more relevant information. The studies on CSO used various diameter filter columns, with anthracite and sand media with and without various dosages of coagulants and/or polyelectrolytes. Removal efficiency for the filter unit was about 65% for SS, 40% for BOD_5, and 60% for chemical oxygen demand (COD). The addition of polyelectrolyte increased the SS removal to 94%, the BOD_5 removal to 65%, and the COD removal to 65%. The average filtration run was 6 h at a hydraulic loading of 24 gal/ft^2/min (59 m^3/m^2/h). SS removal increased as influent SS concentration increased and decreased as hydraulic loading increased.

Dissolved air flotation (DAF) separates solid particles or liquid droplets from a liquid phase by introducing fine air bubbles into the liquid phase. As the bubbles attach to the solid particles, the buoyant force of the combined particle and air bubbles is great enough to cause the particle to rise. Once the particles have floated to the surface, they are removed by skimming. The most common process for forming the air bubbles is to dissolve air into the waste stream under pressure and then release the pressure to allow the air to come out of solution. The pressurized flow carrying the dissolved air to the flotation tank is either the entire stormwater flow, a portion of the stormwater flow (split flow pressurization), or recycled DAF effluent.

Higher overflow rates (1.3 to 10.0 gal/ft^2/min [3.2 to 25 m^3/m^2/h]) and shorter detention times (0.2 to 1.0 h) can be used for DAF when compared with conventional settling (0.2 to 0.7 gal/ft^2/min [0.5 to 1.7 m^3/m^2/h]; 1.0 to 3.0 h). Studies for CSO have shown that a treatment system consisting of screening (using a 297µm aperture with a hydraulic loading rate of 50 gal/ft^2/min [122.3 m^3/m^2/h]) followed by DAF can offer an effective level of treatment. The addition of chemical flocculent in the form of ferric chloride and cationic polyelectrolyte was also shown to improve the removals. There are no data available for treatment of separate storm runoff; however, from the CSO data, it would appear that, except for sedimentation, screening DAF is the most expensive treatment system.

Disinfection of storm runoff requires a different approach from conventional disinfection because the flows have characteristics of intermittency, higher rates, high SS content, wide temperature variation, and variable bacterial quality. Residual disinfecting capability may not be permitted, as chlorine residuals and compounds discharged to natural waters may be harmful to human and aquatic life. Coliform counts are increased by surface runoff in quantities unrelated to pathogenic organism concentration. Total or fecal coliform levels may not be the most useful indication of disinfection requirements and efficiencies. Discharge points requiring disinfection are often at outlying points on the drainage system and require unmanned, automated installations. In addition, a number of nonenteric pathogens found in stormwater runoff have been linked to respiratory illnesses and skin infections.

Table 2 shows disinfectants that might be used for storm flow disinfection. Conventional municipal sewage disinfection generally involves the use of chlorine gas or sodium hypochlorite as the disinfectant. To be effective for disinfection purposes, a contact time of not less than 15 min at peak flowrate and a chlorine residual of 0.2 to 2.0 mg/L are commonly recommended.

The characteristics of storm runoff (i.e., intermittent and often high flows) together with the need to minimize capital costs for a treatment operation lend themselves favorably to use of high-rate disinfection. This refers to achieving either a given percent or a given bacterial count reduction through the use of: decreased disinfectant contact time, increased mixing intensity, increased disinfectant concentration, chemicals having higher oxidizing rates, or various combinations of these. Where contact times are less than 10 min (usually in the range 1 to 5 min), adequate mixing is a critical parameter; it provides complete dispersion of the disinfectant and forces disinfectant contact with the maximum number of microorganisms. Mixing can be done by mechanical flash mixers at the point where disinfectant is

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Table 2. Characteristics of Principal Storm Flow Disinfection Agents

Characteristics	*Chlorine*	*Hypochlorite*	*Chlorine Dioxide*	*Ozone*
Stability	*Stable*	*6-mo half-life*	*Unstable*	*Unstable*
Reacts with ammonia to form chloramines	*Yes*	*Yes*	*No*	*No*
Destroys phenols	*At high concentrations*	*At high concentrations*	*Yes*	*Yes*
Produces a residual	*Yes*	*Yes*	*Short-lived*	*No*
Affected by pH	*More effective at pH < 7.5*	*More effective at pH < 7.5*	*Slightly*	*No*
Hazards	*Toxic*	*Slight*	*Toxic; Explosive*	*Toxic*

added and at intermittent points, or by specially designed plug flow contact chambers containing closely spaced, corrugated parallel baffles that create a meandering path for the wastewater.

Swirl regulators/concentrators are compact flow-throttling and solids-separation devices that also collect floatable material. Swirls are compact units that function as both a regulator for flow control and as a solids concentrator and, when combined with treatment of the relatively heavy settleable solids, can provide an effective treatment system. Performance of swirls is very dependent on the settling characteristics of the solids in the stormwater. The EPA swirl is most effective at removing solids with characteristics similar to grit (≥0.008 in. [0.2 mm] effective diameter, 2.65 specific gravity). It is important to appreciate this aspect of swirl devices and to not expect significant removals of fine and low specific gravity solids.

The three most common configurations are the EPA swirl concentrator, the Fluidsep™ vortex separator, and the Storm King™ hydrodynamic separator. Although each separator is configured differently, operation and the mechanism for solids separation are similar. Flow enters the unit tangentially and follows the perimeter wall of the cylindrical shell, creating a swirling, quiescent vortex flow pattern. The swirling action throttles the influent flow and causes solids to be concentrated at the bottom of the unit. A degritter version of the EPA swirl has also been developed that has no underflow and only removes the grit (detritus) portion.

Beneficial Reuse of Stormwater

The reuse of municipal wastewater for industry, nonpotable domestic usages, and groundwater recharge has been practiced for many years. In 1971, an EPA nationwide survey estimated that current reuse of treated municipal wastewater for industrial water supply, irrigation, and groundwater recharge was 53.5 billion gal/yr, 77 billion gal/yr, and 12 billion gal/yr (200 million m^3/yr, 290 million m^3/yr, and 45 million m^3/yr), respectively. It is reasonable to expect that reuse of treated wastewater and/or stormwater will increase in the future.

Many of the treatments discussed are apt to produce an effluent quality of a higher standard than that required to meet a stormwater permit. The intended reuse will govern the level of treatment required, but careful selection, design, and use of pilot studies should result in the required effluent quality.

Increasing demands on potable water supplies, in particular where a nonpotable water quality standard is required, will make the concept of reuse an increasingly more viable option.

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The complete report, entitled "Stormwater Pollution Abatement Technologies," (Order No. PB95-100053AS; Cost: $19.50, subject to change) will be available from:

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